

## LOSS OF IPSIDIRECTIONAL QUICK PHASES OF TORSIONAL NYSTAGMUS WITH A UNILATERAL MIDBRAIN LESION

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**Abstract**— We report a patient with a long-standing, unilateral lesion of the midbrain who showed ipsidirectional loss of torsional quick phases, impairment of all vertical eye movements and normal horizontal eye movements. The findings are consistent with recent reports of the effects of experimental lesions, in monkeys, of the rostral interstitial nucleus of the medial longitudinal fasciculus and the interstitial nucleus of Cajal.

**Keywords**— midbrain; torsional eye movements; nystagmus; vestibulo-ocular reflex.

### Introduction

Over the past decade, a combination of anatomical, physiological, and lesion studies have defined structures in the midbrain that are important for the control of vertical and torsional eye movements in the rhesus monkey (1). The rostral interstitial nucleus of the medial longitudinal fasciculus (riMLF) has been shown to house the burst neurons that generate vertical and torsional saccades (2-5). The adjacent interstitial nucleus of Cajal (INC) has been shown to play an important role in vertical gaze-holding (the neural integrator) (6,7). Unilateral, experimental lesions of the riMLF result in only a partial defect in vertical saccades, but cause a complete ipsidirectional loss of torsional quick phases (4,5). For example,

a lesion of the right riMLF will abolish quick phases that cause extorsion of the right eye and intorsion of the left eye (corresponding to what has been variously termed positive torsion, dextrocycloverision, or clockwise torsion from the point of view of the subject). Unilateral experimental lesions of the INC are reported to impair gaze-holding function in both the vertical and torsional planes (7). Only recently has it become possible to measure reliably the effects of human midbrain lesions upon torsional eye movements (8,9). We report here a patient with abnormalities of torsional and vertical eye movements due to a unilateral mesencephalic lesion.

### Patient and Methods

A 70-year-old man was referred to the Neurology Service because of recurrent falls. At the age of 25 years, he had abruptly developed a left spastic hemiparesis, left torticollis, and difficulties with vertical gaze. He recovered enough to work as a government clerk, but was left with some torticollis, left-sided shaking, a permanent deficit of vertical gaze, and difficulties with balance. He retired from his job following a myocardial infarction at age 54 years, and was subsequently troubled by recurrent depression. His family reported progression of rigidity and postural instability in the last two years. Since the time of his acute illness, he had undergone numerous diagnostic studies, including pneumoencephalography

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and cerebral arteriography, all of which were reported as normal; no definite diagnosis had been reached. On examination he was depressed but had normal memory; minimal score was 29/30. He had a poverty of facial expression and intermittent blepharospasm. He habitually rubbed his eyes with his right hand. He had a spastic left hemiparesis that hindered his gait. In addition, he had axial rigidity that involved the neck muscles, and a slight head tilt to the left. His eye movement examination is described in the Results section. Magnetic resonance imaging (Figure 1) showed an abnormal signal intensity in the right mesencephalon and adjacent thalamus, involving the cerebral peduncle and dorsal midbrain. Although the quality of the images were limited by the patient's ability to lie still during the procedure, the findings indicated that the lesion was confined to the right side of the mesencephalon and was likely to be an old infarction.

Horizontal, vertical, and torsional rotations of the patient's right eye and head were measured using the magnetic search coil technique (8,9). Since his eye movements were horizontally and vertically conjugate, he viewed binocularly during testing. Fixation and horizontal and vertical saccades were tested by asking the patient to view a laser spot projected onto a tangent screen at a viewing distance of 1.3 meters. This spot was initially stationary at zero position, and then stepped through  $\pm 15^\circ$ , in a predictable pattern, first horizontally and then vertically. In addition, the patient looked between stationary targets located  $\pm 10^\circ$  from the midline in response to the investigator's instructions (that is, we did not attempt to measure saccadic latency). Smooth pursuit was tested as the patient attempted to follow the laser spot moving sinusoidally, in the horizontal or vertical planes, at about 0.5 Hz through  $\pm 15^\circ$ . During testing of fixation, saccades, and smooth pursuit, his head was restrained.

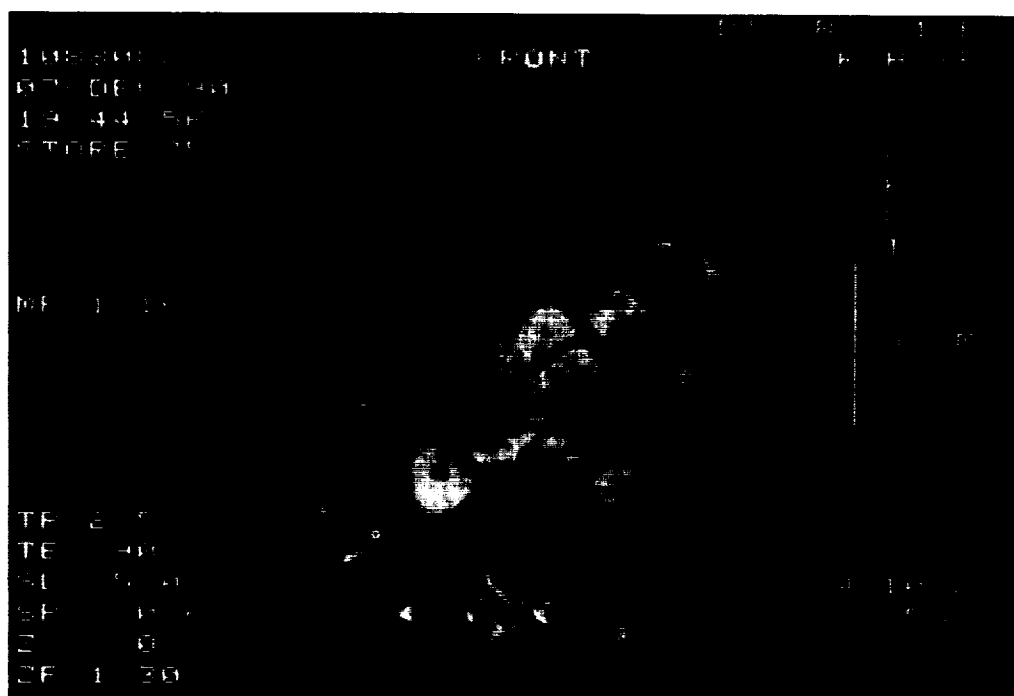
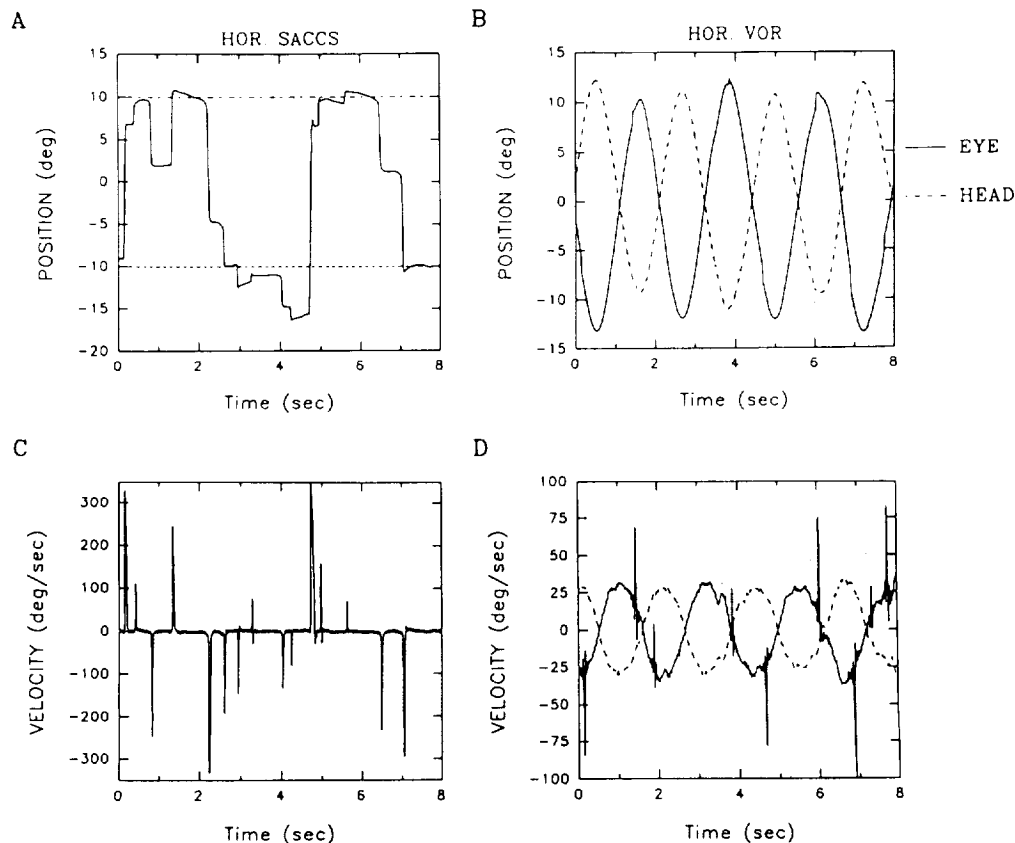


Figure 1. Magnetic resonance image (T2 weighted) showing abnormal increased signal within the right upper midbrain (indicated by arrow) and adjacent thalamus, consistent with an old infarction.

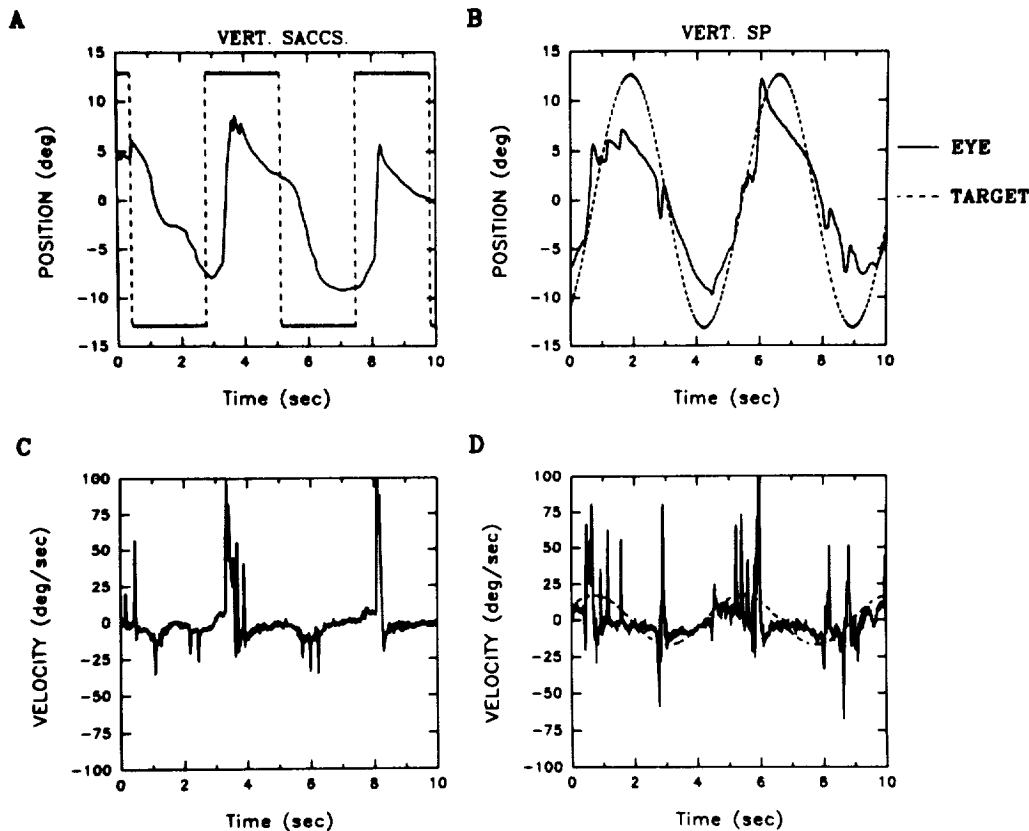
The visually enhanced vestibulo-ocular reflex (VOR) was tested as one of the investigators passively rotated the patient's head, approximately sinusoidally, in yaw, pitch, or roll at about 0.5 Hz through approximately  $\pm 15^\circ$ ; the patient viewed a stationary visual scene. Gaze, head, and visual display signals were digitized at 200 Hz, following analog filtering (Krohn-Hite Butterworth filters, bandwidth 0 to 90 Hz). Data were analyzed interactively, as described previously (10), to provide saccadic amplitude and velocity, and the gain values of smooth pursuit and the visually enhanced VOR in each plane tested.

## Results

Examples of the patient's horizontal eye movements are shown in Figure 2. His saccades were of normal velocity, with some dysmetria (Figure 2A and C). The gain of the visually enhanced VOR was 1.0 (Figure 2B and D). The gain of horizontal smooth pursuit was 0.94 and was symmetrical. In contrast, all vertical eye movements were impaired and restricted in range of movement. Vertical saccades were slow, especially downward (Figure 3A and C). Gaze-holding function was impaired, especially following upward saccades



**Figure 2.** Horizontal eye movements; upward deflections indicate rightward movements. (A) and (C) are corresponding position and velocity records of typical saccades (HOR.SACCs) as the patient looked between two stationary targets (dotted lines). Some of the apparent dysmetria reflected inadvertent visual distraction during this testing. Note that the peak velocities of approximately  $15^\circ$  saccades exceeded  $300^\circ/\text{sec}$ . (B) and (D) are corresponding position and velocity records of the visually-enhanced VOR (HOR.VOR). Note how the gain of the response is close to 1.0.



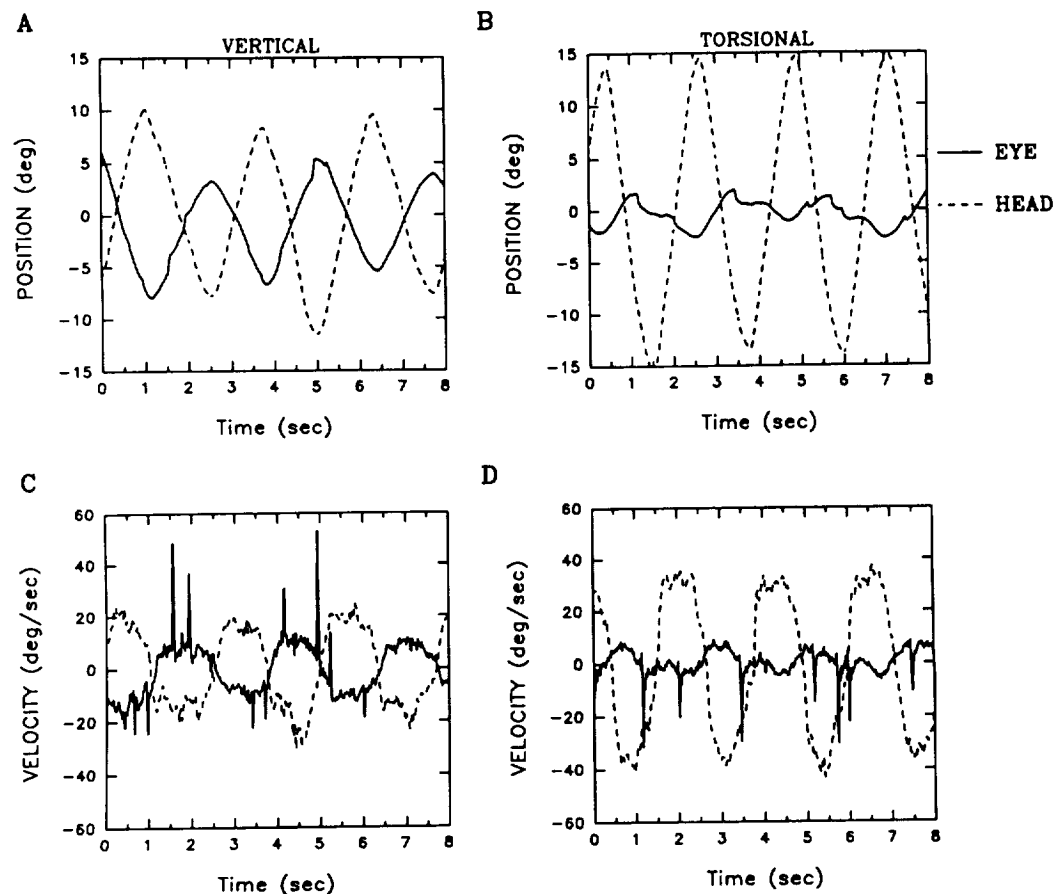
**Figure 3.** Vertical eye movements; upward deflections indicate upward movements. (A) and (C) are corresponding position and velocity records of typical saccades (VERT.SACCES) as the patient attempts to follow step displacements of the visual target. Note that peak velocities are reduced, especially for downward saccades. Also note, in (A), how centripetal drifts of the eyes occur after upward saccades. (B) and (D) are corresponding position and velocity records of the smooth pursuit (VERT.SP). Very few smooth eye movements are generated apart from the centripetal drifts also apparent in (A).

(Figure 3A). Vertical smooth pursuit was severely impaired, and a reliable gain value could not be calculated (Figure 3B and D). The visually-enhanced vertical VOR had a gain of 0.54, but showed only minor asymmetry or phase shift (Figure 4A and C). Vertical quick phases of nystagmus were present both upward and downward, but they were small and slow. In the torsional plane, the gain of the VOR was 0.11, with only minor asymmetry; this gain value is reduced compared with normal subjects (0.21 to 0.77 are 95% confidence limits in a previous study from this laboratory [10]). A consistent finding was that *torsional quick phases occurred only in one direction* — causing intorsion of the right eye and

extorsion of the left eye (negative torsion, levocycloverion, or counter-clockwise rotation with respect to the subject). Torsional quick phases in the opposite direction were absent (Figure 4B and D). During attempted fixation, a low-amplitude nystagmus was present, with quick phases beating levocycloverionally and to the left.

## Discussion

By using the magnetic search coil technique, we have been able to demonstrate, for the first time, a specific disorder of torsional eye movements in a patient with a unilateral midbrain lesion. His right-sided lesion was associated



**Figure 4.** Comparison of the vertical and torsional VOR. Upward deflections indicate head or eye movements upward (panels A and C) or clockwise from the point of view of the patient (panels B and D). Upper panels are position records, and lower panels are corresponding velocity records. In (A) and (C), the visually enhanced vertical VOR has a gain of 0.54. Vertical quick phases occur but these are small and slow, especially downward. In (B) and (D), the visually enhanced torsional VOR has a gain of 0.11. Quick phases of nystagmus occur only in a counterclockwise direction, from the point of view of the patient (levocycloverision), as indicated by downward deflections.

with an ipsidirectional loss of torsional quick phases. This finding is consistent with the results of experimental lesions of the riMLF in monkeys, and supports the hypothesis that each riMLF generates torsional quick phases that rotate the upper pole of each eye ipsilaterally. Such experimental lesions also cause a static ipsidirectional torsional deviation. Our recording technique did not allow us to demonstrate a deviation, although a low-amplitude ipsidirectional nystagmus was noted during attempted fixation with his head stationary.

On the other hand, unilateral, experimental

lesions of the riMLF cause an incomplete defect in vertical saccades, presumably because each nucleus contains burst neurons for both upward and downward movements. In monkeys, a greater deficit in vertical saccades is produced by bilateral lesions in the riMLF; this deficit may be more pronounced for downward eye movements (5,11). Reports of vertical saccadic deficits with unilateral lesions of the riMLF in humans are rare, and may reflect involvement of the commissural pathways of the riMLF that makes the lesion, in effect, bilateral (12,13). Thus, our patient's

slowing of vertical saccades (especially downward) may similarly reflect involvement of commissural pathways. Patients with discrete, bilateral infarction in the region of the riMLF show deficits of either downward or both upward and downward saccades (14). The relative preservation of upward saccades in our patient might be explained by the recent finding that the riMLF projects to motoneurons innervating elevator muscles bilaterally, but to motoneurons innervating depressor muscles ipsilaterally (15,16).

Our patient also showed deficits of gaze holding, smooth pursuit, and the VOR in the vertical plane, as has been previously reported with destructive midbrain lesions (17). Furthermore, the gain of the torsional VOR was reduced. At least some of these deficits, and especially the gaze-holding impairment, might be accounted for by involvement of the INC. Experimental, unilateral lesions of this structure in monkeys indicate that it is important for the neural integration of vertical and torsional eye movements; all classes of versional eye movements would be expected to be affected. Additional evidence for involvement of INC in our patient is the history of acute left torticollis at the time of his midbrain infarction. It is known that the INC also contains neurons that project to motoneurons of the neck and trunk muscles and appears to coordinate combined torsional-vertical movements of the eyes and head. Experimental, unilateral lesions of INC cause a contralateral head tilt, extorsion of the contralateral eye, and intorsion of the ipsilateral eye (6). Stimulation near the INC in the monkey produces an ocular tilt reaction that consists of an ipsi-

lateral head tilt and a synkinetic ocular reaction: depression and extorsion of the eye ipsilateral to the stimulation and elevation and intorsion of the contralateral eye (18). An ocular tilt reaction has been reported clinically in patients with unilateral mesencephalic lesions (19). Our patient showed a slight head tilt contralateral to the side of his MRI findings, but we could not detect a skew deviation, perhaps reflecting the age of the lesion.

It is also possible that pathways projecting to the INC and other midbrain structures were involved by his lesion. The neural signals necessary for vertical vestibular and smooth pursuit eye movements and, to some extent, for the maintenance of vertical eye position (the output of the vertical neural integrator) ascend from the medulla and pons to the midbrain. The medial longitudinal fasciculus is the most important route for these projections, but the brachium conjunctivum and other pathways are also involved (1).

In summary, the advent of reliable methodology for measurement of eye rotations in all three planes has made it possible to identify a hitherto unrecognized disorder of torsional movements. In the future, a combination of clinicopathological correlation and reliable measurement of vertical and torsional and vertical eye movements is likely to further clarify the contributions made by midbrain structures to the control of gaze.

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